AMERICAN BUREAU OF SHIPPING
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ACCEPTANCE STANDARDS FOR NONDEST'RUCTIVE TEST

NOT REQUIRED BY CLASSIFICATION

(PHASE I)

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FOREWORD

This purpose of this report is to present the results of one of the research and development programs which was initiated by the members of the Ship Production Committee of the Society of Naval Architects and Marine Engineers and financed largely by government funds through a cost-sharing contract between the U. S. Maritime Administration and Newport News Shipbuilding. The effort of this project was directed to the exploration of the internal soundness of existing ship hull welds with a view toward providing background information for the development of NDT acceptance guidelines for hull welds located in areas not normally required to be nondestructively inspected for internal soundness for classification.

Mr. M. I. Tanner and Mr. B. C. Howser of Newport News Shipbuilding were Program Managers, Mr. B. L. Alia and Mr. I. L. Stem of American Bureau of Shipping (ABS) were Project Managers, and Mr. D. Ku and Mr. D. Cantore of ABS were the Principal Investigators.

Special acknowledgement is made to the members of welding panel SP-7 of the SNAME Ship Production Committee who served as technical. advisors in the preparation of inquiries and evaluation of subcontract proposals and to Newport News' B.C. Howser and M. I. Tanner for making possible the ultrasonic inspection of the welds and data compilation.

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ABSTRACT

Current nondestructive tests and acceptance standards for radiographic and ultrasonic inspection are generally applicable for full penetration welds in locations within the midship 0.6L such as intersections of butts and seams in the sheer strakes, bilge strakes, deck stringer and keel plates, and butts in and about hatch corners in main decks and in the vicinity of breaks in the superstructure.

At times a shipyard may perform up to 100% nondestructive examination at other locations, for the purpose of internal quality control or to satisfy a contractual agreement. Acceptance standards to apply to locations, which are beyond classification society requirements, are not well defined.

The objective of Phase I of the project was to determine the quality of welds in existing ships that had proven satisfactory in service and use this information as a basis for developing appropriate guidance for nondestructive testing criteria for locations outside classification requirements.

The quality of submerged arc (SAW) deck welds in 18 ships built in the 1943 to 1973 period were evaluated by ultrasonic inspections. Their relationship to an *existing ABS* Rule and a tentative guideline were determined.

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INTRODUCTION (PURPOSE OF WORK)

For ships built to Classification Society Rules, requirements for the nondestructive inspection of ship hull welds for internal soundness by radiography or ultrasonics are governed by ABS Rules for "Nondestructive Inspection of Hull Welds" or equivalents. The Rules do not require 100% inspection, but provide for a representative number of checkpoints governed by the following equation:

n = L (B+D)/500 inch units n = L (B+D)/465 metric units

n = Minimum number of check points

L = Length of the vessel in m or ft. between perpendiculars

B = Greatest molded breadth in m or ft.

D = Molded depth at the side in m or ft. measured at L/2

The location of these check points are indicated in Enclosure 1, the applicable standards and acceptance criteria are indicated in Enclosure 2 and 3 respectively.

The sampling is useful for a quality control measure and does not provide 100% coverage. It is assumed that the inspected areas will be representative of general quality of the welds.

As indicated in Enclosure 1, inspection is directed to intersections, and radiographic or ultrasonic inspection or acceptance standards for welds between intersections is not specifically addressed. At times some additional radiographic or ultrasonic inspection is conducted between intersections, either at an owner's request, or in conjunction with a shipyard's internal quality assurance. Since there are no specific acceptance criteria for the additional inspection beyond Rule requirements, questions as to what is acceptable or nonacceptable become a source of controversy. Consequently there is a need for the establishment of suitable guideline acceptance criteria which could serve as a basis for agreement.

Information as to the quality levels that have proven satisfactory in service is useful in formulating an appropriate acceptance criteria for these areas. Such data is not readily available, but it may be obtained from examination of existing ships.

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The overall objective of this project was to examine the weld quality of existing ships for internal soundness utilizing both radiographic and ultrasonic testing. The initial phase of the investigation is limited to the use of ultrasonic testing with a view toward providing supporting information for the formulation of acceptance criteria for ultrasonic examination of welds between intersections.

APPROACH

The intent of the project was to examine welds for internal. soundness at locations between intersections of existing ships. A problem encountered was the lack of the availability of operating ships, due to reluctance to permit ships to be examined in locations where no inspection requirement existed. However, a MARAD Ready Reserve Fleet located on the James River in Newport News Virginia was made available for the subject study. Initially, representative welds from all ship parts were to be sampled. However, on site inspection of the ships indicated that only deck welds, made by automatic submerged arc processes, were readily accessible for examination.

Shipyard personnel and standard ABS procedures were used for the inspection. The inspection was carried out with a 3/4" X l", 2.25 MHz, 60° angle transduce Indications greater than or equal to the DRL (Disregard Level) (40% of screen height) as defined in Enclosure 4, were to be reported and their length determined.

A total of 18 ships were examined, namely:

- 9 Freighters
- 5 Transports
- 3 Container Ships
- 1 Tanker

These ships were in the 400 to 600 ft range and were built between the years of 1943 and 1973 (see Table I for specific details). A total of 279 inspection locations in the 18 ships were examined; each inspection location consisted of a 24 in. long checkpoint. 70% of the checkpoints were located in the 0.6L midship section of the ships and the other 30% were located outside the midship section . It should be reiterated that only deck welds were examined due to the fact that welds located at the side shell plating of the ships were not readily accessible; for this phase of the investigation, it was deemed desirable to inspect a maximum of weld samples and minimize cost, time and problems involved in inspection of welds in locations not readily accessible (such as side shell)

RESULTS

Results of the inspection are shown in Table IV. Among the 18 ships surveyed, only 7 ships indicated a checkpoint with a recordable indication (above 40% DRL). For the other 11 ships, all of the inspected locations were found free of recordable indications.

ANALYSIS OF RESULTS

An accepted standard for radiographic or ultrasonic inspection of commercial ships is the ABS "Rules for Nondestructive Inspection of Hull Welds". For ultrasonic inspection, Class A and B acceptance criteria apply for various welds and locations as indicated in Enclosure 2.

In this project, two acceptance criteria were used as a basis for weld evaluation (see Table III):

a) One which will be referred to as the "ABS Rules" was the existing ABS Class A and Class B acceptance standards. Class A standards were used for all butts and seams within 0.6L midship and Class B outside midship locations. As previously noted the midship welds between intersections would not be expected *to* be subjected to ultrasonic examination.

b) The second which will be referred to as the "ABS Guidelines" was a guideline acceptance standard that has been proposed by ABS in specific cases where the ship owner or ship designer and the shipyard did not have complete agreement as to the appropriate weld quality for locations where normal inspection was not required. The ABS Guideline indicates, that for intersections, the ABS Rules apply and that for butts between intersections in the midship *area* (0.6L), twice the ABS Class A acceptance criteria would be a reasonable basis for acceptance, and twice ABS Class B for butts between intersections outside the midship areas, and twice ABS Class B for all seams between intersections (midship and outside midship).

DISCUSSION

The overall quality of the ships examined was generally high; 11 out of 18 ships had no recordable indications and the other 7 ships had a low percentage of recordable indications. The fact that only deck welds were examined and that these welds were mainly made by automatic submerged arc welding (SAW) process might have been a factor in the generally high quality of welds.

In terms of checkpoints there was a small difference between rejection under the "ABS Rules" and the "ABS Guidelines" - 19 (6.8%) versus 15 (5.3%). In addition, when the ship with the highest incidence of nonconforming indications was not considered (see Table VI), the difference was even smaller; however, in the case of the "worst ship", the difference in percent acceptance was appreciably greater. Although it is realized that the "worst ship" case does not represent sufficient sampling, it suggests that use of the "ABS Guidelines" in lieu of the "AHS Rules" would have its greatest impact on Poorer workmanship. This trend *was* observed both in the midships and outside of the midship area and applied to the length of discontinuities as well as to the number of checkpoints (Table II).

CONCL*U*SION

The analysis of the results showed that:

overall quality of ship welds examined was generally high

Use of the "ABS Guideline" in lieu of "ABS Rules" to evaluate welds between intersections results in a relatively small reduction of nonconforming welds where workmanship is generally of good quality. However, the reduction increases significantly as weld quality decreases.

The above conclusions are based on data obtained from a limited number of SAW deck welds. In order to confirm these conclusions it would be desirable to obtain additional data from other ships.

FUTURE WORK

The subject program represented an initial effort of a broad program to provide appropriate supporting information upon which to base ultrasonic acceptance guidelines for hull welds located in areas not normally required to be nondestructively inspected. The following additional data regarding the internal soundness of welds for existing ships with satisfactory service experience should be acquired to develop such guidelines:

a) Additional. submerged arc welds (SAW)

b) Welds made with other processes eg. shielded metal. arc (SMAW); and gas metal arc (GMAW)

c) Welds in other locations (i.e. side shell, bottom, turn of bilge, etc.)

d) Welds made in various welding positions (i.e. vertical, overhead)

e) Different thicknesses (1/2" through 2")

f) Welds on ships built in the 1975 - 1981 period.

Similar data should be acquired to develop appropriate radiographic (RT) acceptance guidelines.

A proposal. covering specific facets of work recommended for the next phase will be made after suitable comments have been obtained on the use of data reported herein.

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TABLE I SHIPS SUBJECTED TO ULTRASONIC EXAMINATION

SHIP NO.	TYPE	DIMENSIONS	YEAR BUILT	RECORDABLE INDICATIONS YES / NO
Mvl	Transport	436'.5 X 62' X 38'	1944	*Yes*
MV2	freighter	528'.5 X 76' X 44'.5	1959	*Yes*
MV3	Tanker	503'.5 X 68' X 39'.25	1943	*Yes*
MV4	Container	581'.83 X 78' X 54'.5	1969	*Yes*
MV5	Trsnsport	573' X 75'.5 X 43'.5	1944	*Yes*
Mv6	Freighter	528'.5 X 76' X 35'.5	1952	*Yes*
MV7	Trsnsport	573' X 75'.5 X 43'.5	1945	*Yes*
M v8	Freighter	436'.5 X 62' X 38'	1945	No
MV9	Freighter	436'.5 X 62' X 38'	1945	*No*
Mvlo	Freighter	436'.5 X 62' X 38'	1957	*No*
Mvll	Transport	436'.5 X 62' X 38'	1945	*No*
MV12	Transport	436'.5 X 62' X 38'	1944	*No*
MV13	Freighter	470' X 73' X 42'.17	1960	*No*
MV14	Freighter	470' X 73' X 42'.17	1961	*No*
MV15	Container	581'.83 X 78' X 54'.5	1969	*No*
MV16	Container	581',83 X 78' X 54'.5	1973	*No*
Mv17	Freighter	470' X 73' X 42'.17	1960	*No*
MV18	Freighter	541' X 75' X 42'.83	1962	*No*

TABLE II

SUMMARY OF UT SURVEY

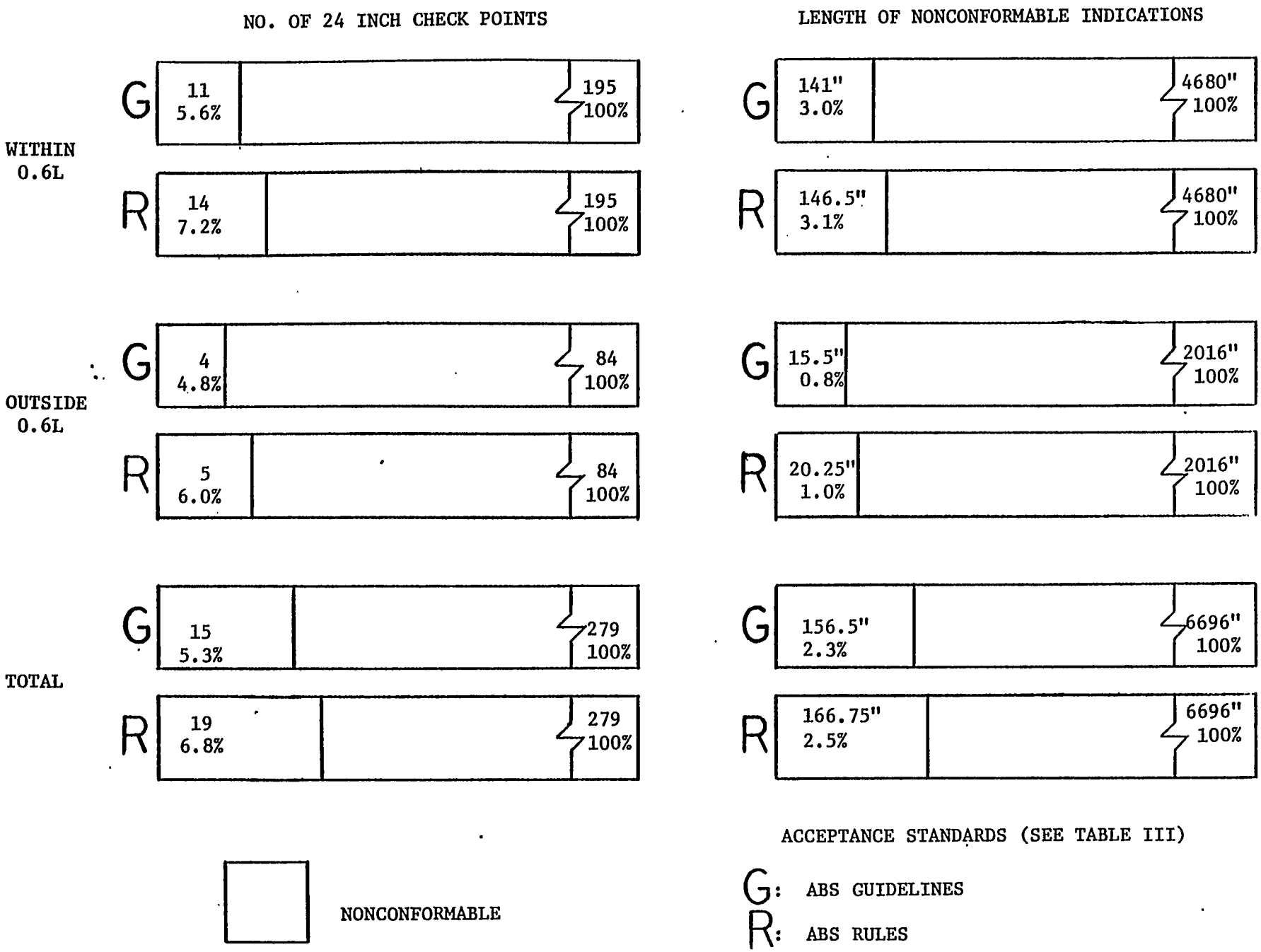


TABLE III

NONDESTRUCTIVE TESTING ACCEPTANCE CRITERIA

	AT INTERSECTIONS		BETWEEN INTERSECTIONS			
	Within Midship 0.6L	Outside Midship	Within Midship 0.6L		Outside Midship	
			Butts	Seams	Butts	Seams
ABS Rules	A*	B*	—	—	—	—
ABS Guidelines	A*	B*	2A	2B	2B	2B

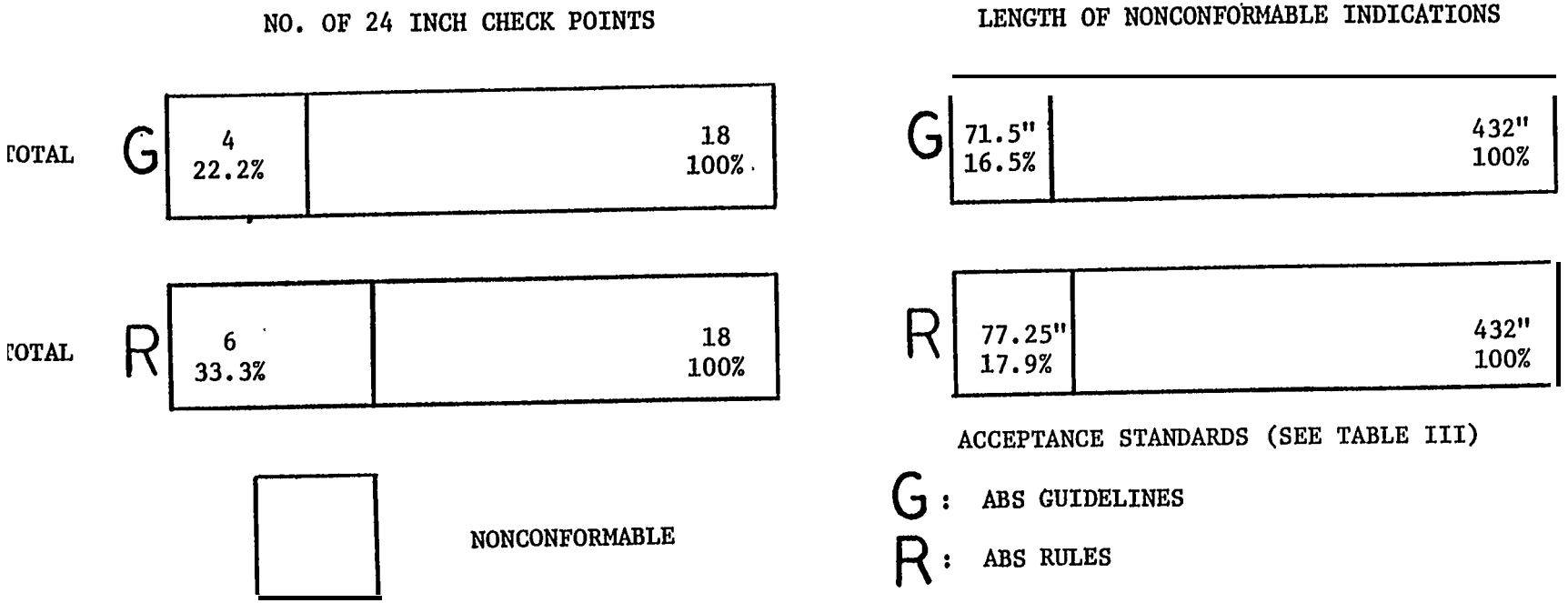
* As defined in Enclosure 3.

TABLE IV
SHIPS WITH RECORDABLE INDICATIONS

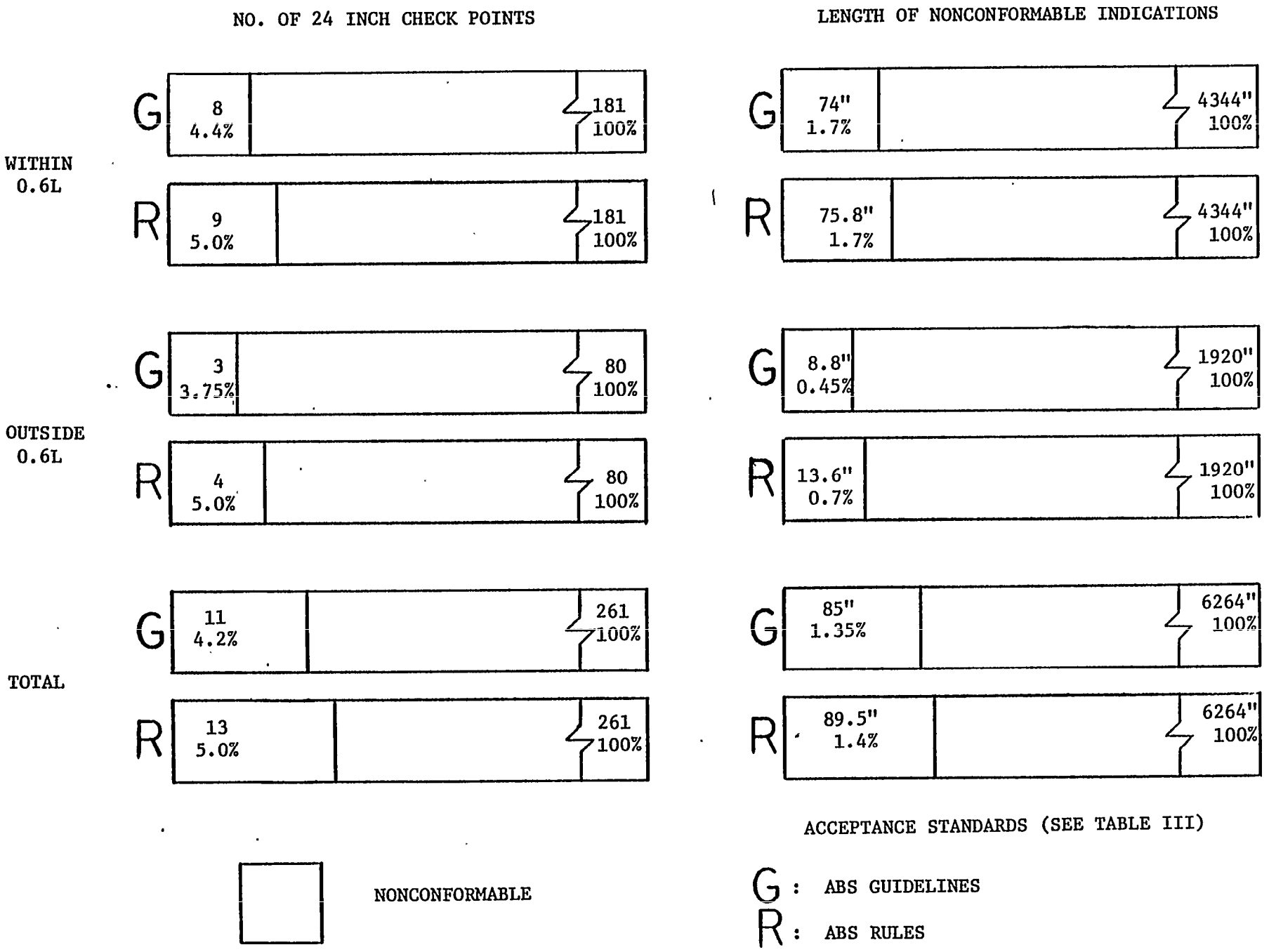
SHIP	NO. OF CHECK POINTS BUTT (B) SEAM (S)	TOTAL LENGTH INSPECTED (INCH)	NO. OF CHECK POINTS RECORDABLE INDICATION	PLATE THICKNESS (INCH)	SCREEN HEIGHT (%)	LENGTH OF INDICATION (INCH)	ACCEPTANCE CRITERIA	MIDSHIP LOCATION YES, NO
MV1	14 (B)	336	5	0.8 (B)	50	2	2A	NO
				0.9 (B)	70	3	NA	YES
				0.92 (B)	60	2-3/4	2B	YES
				0.92 (B)	80	2-3/4	2B	YES
				0.92 (B)	70	.5	NA	NO
						T:15-1/2		
MV2	18 (B)	432	1	1.135(B)	90	13	NA	YES
MV3	11 (B)	384	1	0.85 (B)	50	2-1/2	NA	YES
	5 (S)							
MV4	22 (B)	528	2	0.94 (B)	50	3	NA	NO
				0.94 (B)	50, 60	2-3/4, 3		
						T: 8-3/4		
MV5	13 (B)	336	2	0.8 (B)	100	24	NA	YES
	1 (S)			0.8 (B)	100	22	NA	YES
						T:46		
MV6	5 (B)	264	2	0.96 (S)	50	1-3/4	2A	YES
	6 (S)			0.92 (B)	70	4	NA	YES
						T: 5-3/4		
MV7	10 (B)	432	8	0.85 (B)	100	24	NA	YES
	8 (S)			0.85 (S)	40	1-7/8	2A	YES
				0.85 (S)	80, 100, 60, 50	2-3/4, 1-3/4, 1-3/8, 3/4	NA	NO
				0.85 (B)	60	1	A	YES
				0.85 (S)	100	19	NA	YES
				0.96 (B)	100	24	NA	YES
				1.25 (B)	40	7/8	A	YES
				1.25 (B)	70	1-3/4	2A	YES
						T:79-1/8		

TABLE V

SHIP WITH HIGHEST INCIDENCE OF
NONCONFORMABLE INDICATIONS
(TRANSPORT, 573', 1945)



SUMMARY OF OT SURVEY EXCLUSIVE OF
SHIP WITH HIGHEST INCIDENCE OF
NONCONFORMABLE INDICATIONS (TABLE V)



ENCLOSURE 1

EXCERPT FROM ABS 1975 "RULES FOR NONDESTRUCTIVE INSPECTION OF HULL WELDS"

2.4 Location of Ultasonic Inspection

2.4.1 critical Locations

a Surface Vessels Ultrasonic inspection within the midship *0.6L* **is** to be carried out mainly in locations such as intersections of butts and seams in the sheer strakes. bilge strakes, deck stringer and keel plates, and butts in and about hatch comers in main decks and in the vicinity of breaks in the superstructure. Particular attention is to be directed to field erection joints and any suspected problem areas. Where inspection is to be carried out at weld intersections a minimum of 250 mm (10 in.) of we1d measured from the intersection in each direction transverse to the axis of the vessel (butt weld). is to be inspected. In addition, a minimum of 125 mm (5 in.) of weld measured from the intersection in each direction longitudinal to the axis of the vessel (seam weld), is to be inspected.

b Other Marine *Structures* *Ultrasonic* inspection is to be carried out mainly in areas which may be subjected to high stresses. In the case of column support structures, particular attention is to be given to the intersection of *longitudinal seam* welds with circumferential butt welds.

2.4.2 Other Locations

a. Surface Vessels Ultrasonic inspection outside the midship *0.6L is* to be carried out at random in important. locations such as those specified in 2.4.la above at the discretion of the Surveyor.

b Other *Marine Structures* Ultrasonic inspection in other *than* the critical locations indicated in 2.4lb is to be made at the discretion of the *Surveyor.*

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ENCLOSURE 2

EXCERPT FROM ABS 1975 "RULES FOR NONDESTRUCTIVE INSPECTION OF HULL WELDS"

2.5 Applicable Standards

2.5.1 Class A

a Surface Vessels *Ultrasonic* inspection of full penetration welds for all surface vessels 150 m (500 ft) and over, in the critical locations indicated in 2.4.la, is to meet the requirements of Class A. Class A may also be specified and applied to surface vessels less than 150 m (500 ft) when special hull material or hull design justifies this severity level.

b Other Marine Structures Ultrasonic impection of full penetration welds in critical locations such as those indicated in 2.4.lb is to meet the requirement of Class A.

c Liquefied Natural Gas (LNG) and Liquefied *Petroleum Gas* *(LPG) Carriers Ultrasonic* inspection of full penetration welds in wav of integral or independent tanks of all vessels intended to carry LNG or LPG cargo is to meet the requirements of Class A.

***2.5.2 Class* B**

a Surface Vessels Ultrasonic impection of full penetration welds for surface vessels under 150 m (500'ft) and for the other locations indicated in 2.4.% regardless of the size of the vessels is to meet the requirements of Class B provided that Class A has not been specified in accordance with the special conditions noted in 2.5.la

b Other Marine Structures Ultrasonic inspection of full penetration welds for the *other locations* indicated in 24.2b is to meet the requirements of Class B.

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ENCLOSURE 3

EXCERPT FROM ABS 1975 "RULES FOR NONDESTRUCTIVE INSPECTION OF HULL WELDS"

2.6 .Acceptance Criteria

2.6.1 Class A

a *Indications Greater than the ARL* Welds in which the ultrasonic indications produce a signal which exceeds the ARL (as "estab lished in 2.2.7) and has a length greater than 12.5 mm (0.50 in.) are unacceptable. Indications less than 4.8 mm (0.187 m.) m *length* may be disregarded. Indications 4.8 mm (0.187 in.) to 12.5 mm (0.50 in.) in length are to be evaluated in 'accordance with 2.6:lb.

b *Indications Greater than the DRL* Welds in which ultrasonic indications produce signals which are greater than the DRL are unacceptable if the signals are indicative of discontinuities greater in length than those shown in the respective curves of Figures 2.5 and 2.6 for single or total accumulated]ength. Indications less than 4.8 mm (0.187 in.) in length may be disregarded.

c Indication Less *than the DR.L Ultrasonic signals* which are less than the DRL *are* to be disregarded.

2.6.2 Class *B*

a Indications Greater *than the ARL* *Welds* in which the ultrasonic indications produce a signal which exceeds the ARL (as established in 2.2.7) and has a length greater than 12.5 mm (0.50 in.) are unacceptable. Indications less than 4.8 mm (0.187 in.) in length may be disregarded. Indications 4.8 mm (0.187 in:) to 12.5 mm (0.50 in.) in length are to be evaluated in accordance with 2.6.2b.

b Indications *Greater* than the *DRL* Welds in which ultrasonic indications produce signals which are greater than the DRL are unacceptable if the signals are indicative of discontinuities greater in length than those shown in the respective curves of Figures 2.5 and 2.6 for single or total accumulated length. Indications less than 4.8 mm (0.187 in.) in length may he disregarded.

c Indications' Less than the *DRL* *Ultrasonic signals which are less than the* DRL *are* to be disregarded.

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ENCLOSURE 4

EXCERPT FROM ABS 1975 "RULES FOR NONDESTRUCTIVE INSPECTION OF HULL WELDS"

2.2.8 Weld Inspection

a Longitudinal *Discontinuities* In order to detect longitudinal discontinuities which maybe present in welds or heat affected zones the transducer is to be moved in a Selectd overlapping pattern similar to that shown in Figure 2.3. SimultaneouslyOUS1y while moving along the path of inspection, the transducer is to be oscillated through a small angle. The length of weld to be inspected is to be scanned with the transducer directed in two distinct paths; either or both sides of the weld from the same surface, or on. opposite surfaces from the same side of the weld.

b *Transcerse Discontinuities* *In* order to detect transverse discontinuities which may be present in welds, the transducer is to be angled about 15 degrees from the weld axis and moved parallel to the weld length as shown in Figure 2,3. The scan is to then be repeated on the same surface (if accessible) on the other side of the weld Both scans are to be made with the *transdicer* moved in the same *direction.* Alternatively, where inspection is not accessible from the same surface on both sides of a weld. *a second scan is to be* made on the opposite surface from either side of the weld. For welds in which the surfaces have been ground the transducer is placed on the weld surface and moved along the weld axis with the sound beam directed parallel to the weld

2.2.9 Discontinuity Length Determination

When discontinuities are indicated the sound beam is *to be directed so as* to maximize the signal amplitude. The transducer is then moved parallel to the discontinuity and away from the position of maximum signal amplitude until the indication drops toward the base line. Using the center line of the wedge of the transducer as au index the extremity points of the discontinuities are determind as indicated in a and b.

a Indications Greater than ARL For indications with peak amplitudes greater than the AM (over 80% of full screen height), the extremity points of the discontinuity are defined as the points at which the signal drops to 40% of full screen height

b *Indications Greater* than *DRL* For indications with peak amplitudes of 80% *or less* of full screen height the extremity points of the discontinuity are defined as the points where the signal amplitude either remains below the DRL (40% of full screen height) for a distance equal to ½ the major dimension of the transducer or drops to ½ the peak amplitude. whichever occurs first (i.e. the points which define the shortest discontinuity length).

2.2.10 Ultrasonic Inspection Reports

Ultrasonic inspection reports are to be fried for record and are to include the hull number, exact location and length of the welds inspected equipment used (instrument identity. transducer type, size. frequency, angle) base metal type and thickness. weld process, any unusual condition of weld bead (ground, undercut, etc.) weld joint design, the specific class to which examination is being carried out and all reflections which are interpreted as failing to meet the specified requirements (as defined in 2.6,), dates of inspection and signature of ultrasonic operator. (A typical report form. shown in Figure 2.4, is considered acceptable) The method for review and evaluation of ultrasonic test reports is *to assure* adequate quality control and is to be to the satisfaction of the Surveyor.